ANSWERS

OF

SIR WILLIAM THOMSON, PROFESSOR FORBES, DR. HOPKINSON,
W. H. PREECE AND E. FESQUET,

TO

TEN QUESTIONS

REGARDING THE

COMMERCIAL USE OF ELECTRICITY IN ELECTRIC LIGHTING.

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NOTE.

The recent discussion in the United States and more especially in New York City, regarding the use of electricity for lighting and power purposes, has suggested the idea of securing the opinions upon the mooted questions, of several of the most prominent and experienced electricians in Europe. With this in view the ten questions hereinafter given were prepared with great care and submitted to Sir William Thomson, Professor George Forbes, Doctor John Hopkinson, W. H. Preece and E. Fesquet. The first four were chosen as, perhaps, the most eminent experts in the science of electricity in Great Britain, and Mr. Fesquet because of his long practical experience with central station electric lighting in London. The answers of these gentlemen are given in full, without change or omission. The original answers duly signed, verified before a notary public and certified by a United States Consular officer, are in the possession of Dr. Henry Morton, President of Stevens Institute of Technology, at Hoboken, N. J.

The testimony of these gentlemen is especially valuable, not only because of their eminence and experience, but because they are out of reach of local influences and prejucices and speak simply as scientists.

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QUESTIONS.

1. Can high tension direct and alternating currents for lighting and power purposes be safely and successfully distributed by means of underground cables? If so, up to what voltage can this be done?

2. If your answer to question 1 is in the affirmative, state whether your opinion is based upon theory or upon knowledge of what has actually been done. If the latter, give a full statement of the facts upon which you base your opinion, showing, as far as possible, the extent to which high tension currents, both direct and alternating, have been distributed by means of underground cables in the various cities of the United Kingdom and the Continent; the length of time during which cables now in successful operation have been in use; the voltage of currents thus distributed in various cities, and the approximate number of lights operated in various cities by means of such cables.

3. Give some idea of the character of the cables used and the manner in which they are laid.

4. What is your opinion as to the safety to the consumer and the public at large, of the converter or transformer system of electric lighting, involving the use of high tension alternating currents in the street mains?

5. What is your opinion as to the relative fire danger in the transformer or converter system and in the low tension direct current system, respectively?

6. In your opinion, is the converter or transformer an effectual safeguard to protect the user of electric illumination from danger, from shock or fire?

7. State to what extent the converter or transformer system is now being used in London and other cities in Europe for lighting from central stations, as compared with the low tension direct current system, and in favor of which of the two systems the present development in electric lighting in Europe seems to be?

8. Explain to what extent high tension currents, direct and alternating, are necessary for the successful and economical distribution of electricity for lighting and power purposes, and state what, in your opinion, would be the effect upon the electric light and power industry, and the interests of the public in general, in case the use of high tension direct and alternating currents was abandoned, and all lighting and power work done exclusively by means of the low tension direct current system?

9. Can high tension, direct and alternating currents be safely distributed by means of overhead conductors? If so, under what circumstances, and by means of what precautions?

10. Kindly make any other suggestions which occur to you which will bear upon the present discussion in the United States as to the conditions under which electric lighting from central stations can be most safely, successfully and economically done?

ANSWERS OF SIR WILLIAM THOMSON.

1. Yes, I believe so, up to 2,500 volts.

2. My opinion is primarily based on general knowledge of the insulating power of the materials used for insulating the conductors of submarine cables and electric light systems, and on measurements made in my own laboratory of voltage required to break down insulations of different kinds. A very small thickness of insulation suffices to resist 2,500 volts, and practically moderate thicknesses are not broken down with 5,000 or 6,000 volts, and are very safe with 2,500, whether direct or alternating. There has not hitherto, so far as I know, been very much practical experience of 2,500 volts on underground conductors in electric lighting, but I have great confidence that it can be carried out, whether with direct or alternating currents, successfully and with every promise of durability of the materials.

3. A great variety of plans may be used safely and successfully for both direct and alternating currents. One method for alternating currents consists in placing the two conductors as coaxal cylinders, having sufficiently thick space between them filled with insulating material; surrounding the outer conductor with a less thick layer of insulating material, and enclosing the whole in a lead or iron pipe. The conductors for this system may be copper tubes, but it is generally preferable to make them of wire strands laid with a moderate twist on the proper cylindric surfaces. The inner conductor should be of six strands laid spirally as close together as possible, on a hempen or other non-metallic core. Each wire should be

prevented from metallic contact with its neighbors by slight insulation. This method gives practically absolute security against danger to the public.

4. With properly laid mains the high tension alternating currents in the street mains underground, involve I believe no danger whatever, to the public at large. The converter or transformer system can, I believe, be made absolutely safe to the consumers by proper arrangements. It has already been largely practiced in London, Glasgow and elsewhere; and as far as I know, no instance has occurred of any consumer having met with an accident.

5. In the event of the escape of gas, in the neighborhood of the high tension mains, the high tension alternating current may set it on fire; but probably not so the low tension direct current. Within a house or building in which the electric light is used, the danger of fire is not materially different in the two cases, and in either it may be practically annulled by proper arrangements. I believe also, that the transformer itself, when properly constructed, and properly mounted and guarded, does not cause any danger of fire.

6. In my opinion, the transformer, when properly made, properly mounted and supplied with proper safeguards, is thoroughly effective to protect the user of electric illumination from danger from shock or fire.

7. The present development of electric lighting in Europe seems to be in favor of the transformer system on the whole, because of the facilities it gives for transmitting the electric energy over great distances with moderate amounts of copper.

8. The mass of copper required for the economical transmission of electric power to distances of more than a mile is so great, relatively, to the value of the work done, if the potential be limited to 100 or 200 volts that in my opinion it would be fatal to the electric light and power industry, and to the interests of the public in general to abandon the use of much higher potentials than 200 volts.

9. Yes, I believe perfectly and easily, except in cities; and even in cities by the observance of the rules for public safety which have been imposed by the British Board of Trade. For the transmission to great distances over the country I believe electric energy can be conveyed by currents, whether direct or alternating, through a pair of bare copper wires, at a distance of from five inches to a foot from one another, insulated by porcelain or glass insulators, and supported on poles, with perfect safety to the public. The requisite security against the possibility of electric damage to man or beast, through breakage of a wire or blowing down of poles, can, I believe, be made practically perfect by proper appliances.

10. The comparatively small currents required in the mains on the high tension alternate current system give it many advantages over all low tension systems: as, for instance, the smallness of the conductors and consequent ease of laying as well as economy of prime cost; and the security against any current strong enough to do damage underground or elsewhere being allowed at any time to pass through them, through any accidental short-circuiting at crossings.

(Signed) WILLIAM THOMSON.

Subscribed in my presence and sworn to before me this 28th day of February, A. D. 1890.

IN WITNESS WHEREOF, I hereto subscribe my name officially and affix the seal of the Consulate of the United States at Glasgow, Scotland. [SEAL.]

LEVI W. BROWN,

U. S. Consul, City and District of Glasgow, Scotland.

CONSUATE GENERAL OF THE UNITED STATES OF AMERICA FOR GREAT BRITAIN AND IREAND AT LONDON.

I, John C. New, Consul-General of the United States of America at London, England, do hereby make known and certify to all whom it may concern that John Venn, who hath signed the annexed certificate, is a Notary Public, duly admitted and sworn and practicing in the City of London, aforesaid, and that to all acts by him so done full faith and credit are and ought to be given in judicature and thereout.

In testimony whereof, I have hereunto set my hand and affixed my seal of office at London, aforesaid, this first day of March, in the year of our Lord one thousand eight hundred and ninety.

[SEAL.]

JOHN C. NEW,
Consul-General.

[Postage and Revenue Stamp.]

I, JOHN VENN, of the City of London, Notary Public, duly admitted and sworn, praictising in the said city, do hereby certify and attest:

That the statement hereunto annexed marked "A," and the supplemental statement also hereunto annexed marked "B," were this day signed in my presence by Professor George Forbes of No. 34 Great George street, London, Consulting Engineer.

Whereof an act being required, I, the said notary have granted these presents under my notarial firm and seal to serve and avail when and where need may require.

Done and passed in London the first day of March, in the year of our Lord one thousand eight hundred and ninety.

[SEAL.]

JOHN VENN,
Not. Pub.

ANSWERS OF PROF. FORBES.

1. We have ample proof that high pressure electric currents, either direct or alternating, can be distributed safely and successfully, for lighting purposes, by means of underground cables. Our experience in the past has been limited to 2,500 volts, as a maximum, and up to this pressure there has been no difficulty whatever, in any case where care has been taken to secure a good and durable type of insulation to the conductors, and to protect them from mechanical, chemical, and other sources of deterioration. It would be unwise to hazard an opinion as to the highest pressure which can be properly used in underground electric mains, until we have experience to guide us. While we have ample data as to insulation and durability under ordinary conditions, yet there are certain phenomena, of whose existence we are aware, when very high pressure (say 10,000 volts) are used, which may, or may not, create difficulties with these high pressures. Until we have further experience, I would not advise any one to run the risk of making the supply of current irregular through defective insulation, and for this reason I would not recommend, at this date, the use in underground mains of a higher pressure alternating current than 2,500 volts, except in way of experiment.

2. The opinion expressed above is founded upon experience and knowledge of what has been done, and after paying most special attention to this part of the subject for many years, and after having inspected within the last fourteen months the most important electric light works in Great Britain, the Continent of Europe and America.

In London, the London Electric Supply Corporation has had several miles of underground cable working at 2,400 volts (alternating) for several years. These cables are of best quality vulcanized india-rubber, laid in cast-iron pipes.

The Eastbourne Electric Lighting Company began work eight or nine years ago, with 2,000 volts continuous current supplied by underground conductors. At Hastings the same action was taken at the same time by an allied company. Three years ago the continuous current at Eastbourne was abandoned, and an alternating current of 2,000 volts was substituted, new underground mains being used. During all this time the condition of the cables has been perfectly satisfactory. In each of these towns the circuits cover some eight to ten miles, and there has been no case of fire, nor any loss of life.

Another allied company is the House to House Company in London, which has a very fine central station, working alternating currents at 2,000 volts, and has several miles of mains. These cables are generally copper covered, with jute fibre impregnated with bituminous compound, and covered with lead. They are laid in cast-iron pipes, with frequent man-holes.

At Rome, in January, 1889, there were 17 kilometres of underground mains distributing alternating currents at 2,000 volts. These were stranded concentric cables, insulated with impregnated jute, encased in lead, served with protective compound, armor-clad with iron strips, and further protected by an outer serving of tarred hemp. These have been at work for over two years, and at the date mentioned (January. 1889) were supplying 9,000 incandescent lamps of 16-candle power, and 200 arc lamps.

At Milan, in January, 1889, there were some miles of similar cable distributing alternating currents at 2,000 volts, supplying about 1,600 lights of 16 candle power.

At Nancy (France), there were 10,000 lights in April, 1889. These are supplied by alternating currents at 2,400 volts, by means of underground mains, to which connections are made every few yards. The mains consist of stranded concentric cores, insulated and protected by iron wire strand.

At Tours (France), three years ago, the mains for working a 2,000 volt alternating system were replaced by cables insulated with vulcanized india-rubber, to the extent of six or seven miles, which have worked satisfactorily.

High pressure continuous currents have been worked through un-

derground cables at the Silvertown Electric Works for about eight years without any trouble. The insulation is high class vulcanized india-rubber.

Numerous other cases might be quoted. I mention those which have come under my special observation. In all of these cases the cables have worked satisfactorily. There has been absolute safety, hardly ever any irregularity in the supply and remarkable freedom from fires.

3. The types of cable which have done such good service for high pressure work, are generally known in the trade by the follow ing names :

(1) The Silvertown vulcanized india-rubber cables.

(2) The Siemens concentric cables.

A year ago I had occasion to draw attention to serious breakdowns in the lead-covered type of cable in the electric lighting system of Berlin. This system is worked at low pressure, and very large conductors must be used. The outside of the cable is some three inches in diameter, and when coiling this on a four-foot drum, I conceive it to be quite possible that the lead is severely strained, and, becoming punctured, admits water. This is not so much to be feared with the smaller cables used with high-pressure currents.

As to the manner of laying the conductors, the Siemens concentric cables being ironclad, and being generally laid under the footway, do not require any further protection. In crossing streets they are generally run in pipes.

The vulcanized india-rubber cables are laid in wooden boxes, concrete troughs, or iron pipes. The last of these plans is the most generally adopted. Vulcanized rubber can only be used when of the best material. It then cannot be excelled. Its quality for durability may be judged by tests of its insulation resistance.

The lead covered cables are now generally drawn into iron pipes.

The weak part of a cable is at the junctions to the service lines. Special care must be paid to the manner of insulating these joints.

4. Previous to 1885, when a low pressure system alone was available, engineers were in search of some high pressure system which

would reduce the copper required to a reasonable amount. Their attempts were mainly in the direction of a parallel series system. But they could not recommend it, because of the danger from defective insulation in the house wiring causing high pressure shocks to the consumers. After the alternating current transformer system had been proved to be efficient, it was accepted as the required solution of the difficulty, because the house wiring is, on this system, completely separated from the street mains. Every one in this country who then came to this conclusion, and has had experience of the system, has been confirmed in his belief that the transformer secured the required safety.

5. In a low pressure net-work system of mains, the resistance is very low, so that if a short circuit occurs in any house wiring (or, if the mains leak, a connection of the house wiring to earth suffices), it is quite possible to have 10,000 amperes, or more, going through these house wires, previous to the going of the fuse, even if the fuse is in good working order. This current, even if it lasts only a small fraction of a second, is able to cause fire-risks. With the transformer system this is not at all the case. The possible current is here limited by the size of the transformer; in the direct supply system it is limited only by the possible output of the central station. The transformer system is safer, because the house wiring is detached from street mains. If the street mains have a bad leak, a contact of the house wiring with gas or water pipes may cause a fire on the direct system, but not so on the transformer system. With proper precautions, however, strictly enforced, as in England, to prevent a short-circuiting of the house wiring, and to prevent leakage from the street mains to earth, both systems are absolutely safe.

6. If the transformer has its primary and secondary coils made separately and insulated separately, and if fuses are placed in both primary and secondary circuits, and if the mechanical construction is such that there is no rubbing and wearing of the insulation between primary and secondary coils, then the transformer is an absolute protection to the consumer against fire and life risks. All these requirements can easily be fulfilled. Major Cardew's safety device

suffices to render even bad transformers a protection to the consumer.

7. The best idea that can be obtained as to the relative use of low pressure direct supply, and high pressure alternating current transformer supply, at the present time, is to be got by analyzing the evidence given before Major Marindin, at the Board of Trade Enquiry on the Electric Lighting of London, in 1889. The following table shows the companies which were given powers for one or other of these two systems, the capital which had been authorized, the amount which had been paid up at the date of the inquiry, and the number of square miles in London allotted to them:

LOW PRESSURE DIRECT SUPPLY.

	Authorized Capital.	Paid up Capital.	Area, Square Miles
Westminster Electric Supply Corporation	£100,000	£8,000	1.5
Kensington and Knightsbridge Electric Lighting Company	250,000	37,240	1.1
St. James and Pall Mall Elec. Light Company	100,000	26,000	0.3
Total	£450,000	£71,240	2.9

HIGH PRESSURE TRANSFORMER SUPPLY.

	Authorized Capital.	Paid-up Capital.	Area, Square Miles
London Electric Supply Corporation.	£1,250,000	£585,000	5.3
Metropolitan Electric Supply Company	500,000	152,732	3.7
House to House Electric Light Supply Company	350,000	41,600	1.1
Total	£2,100,000	£779,332	10.1

The most certain way of judging of the comparative amount of business being done by the several companies is, to compare the paid-up capital in each case. Here we find that the companies working on the low pressure direct supply system had contributed 8.4 per cent. of the total paid up capital, while those using the high pressure alternating system had contributed 91.6 per cent. of the total paid-up capital. I should mention the fact that a small area was allotted to a company called the Electricity Supply Corporation, but I can find no evidence in the reports as to what system they are to adopt, nor any facts about their capital. The Notting Hill Company, so far as I can learn, is not doing anything. The Chelsea Company is a high pressure supply, reduced in pressure by batteries.

The general evidence elsewhere in England and Europe generally is that at present high pressure is most generally adopted, and almost always on the alternating current system. A very significant fact is that Mr. Crompton, who was a most able advocate of the low pressure system, has lately secured the contract for lighting the town of Chelmsford, and has himself selected the alternating high pressure system with transformers. It is my firm conviction that at present and until a storage battery is found which is cheap, efficient and durable, most of our municipal lighting in Europe, including Great Britain, will be on the alternate current high pressure transformer system, and that only in exceptional cases can a low pressure supply be economically given.

8. The reason why electric lighting from central stations made no progress in England till 1885, was only in part due to the electric lighting act. It was mainly due to the fact that electricians saw that the copper required for feeders from a central station, to supply 100,000 lamps on the three-wire low tension system, on the most economical principles, must have a total section of at least 50 square inches each, which is impractical. They resolved to wait until a satisfactory high tension system should be worked out. Of these, the parallel-series system could not be adopted, because the house wiring was in direct connection with high pressure mains. The storage battery system might

have been used, if the efficiency, economy and durability of these were sufficient for practical work on a large scale. Even now, the secondary battery has not been sufficiently perfected in these directions. If it were it would be very generally adopted. The transformer system is the only one which has satisfied those engineers here who have had experience, as an economical and safe means of converting high into low pressure. For large towns high pressure is a necessity, especially in America, where the houses which are to be supplied are often at great distances from each other. If high-pressure systems were abolished in England electric lighting would, from an engineering point of view, be in the same position as five years ago. Central stations could then be started only in extremely concentrated districts where light is used up to late hours.

9. High-pressure direct or alternating currents can be safely distributed by means of overhead conductors, if proper rules are made, and means arranged for enforcing them. In the last five years the central station at the Grosvenor Gallery in London has supplied by overhead conductors alternating current at 2,400 volts to about 15,000 sixteen candle power lamps, or the equivalent. The contractors foresaw that carelessness on their part might lead to accidents, and so to condemnation of their works. The work was all of the best. Best vulcanized india-rubber insulation braided, was used, and the mechanical construction of the lines was excellent. The cables are all supported by insulating suspenders on a steel wire. The supports are all firmly stayed on the tops of houses. Inspection of these is perfectly easy. There has never been a death from shock, except perhaps one, where, however, the sufferer fell from a house roof, and the cause of death was uncertain. Fires on this system have been almost unknown. The rules for overhead wires, prepared by the Board of Trade, are in my opinion more than sufficient for the protection of the public. Aesthetic considerations prevent us at present from suspending our cables on poles in the streets. In towns where elevated railroads are allowed in the streets, I do not think that this consideration need have much weight.

10. I have been in the United States this year, and seen the con-

dition in which New York City is at present. This would all have been prevented, if the electric lighting companies had looked to permanent rather than temporary profits; if the Board of Electrical Control had been composed of able and unbiased electrical engineers; or if the civic authorities had not lost their heads. It has been a foolish thing to insist on putting the wires all underground, if the public have a right to expect the most for their money. The cost of electric light will be thus increased fully 50 per cent. What ought to be done is to register every electric light wire, and subject it to strict regulations, such as those issued by the English Board of Trade, under the advice of the Institution of Electrical Engineers. Of course it is only high pressure mains which could be carried overhead for light and power purposes. Low pressure ones would be too large. If panic legislation were to stop the use of high-pressure currents of electricity the public would be largely deprived of a great boon. I must qualify my remarks by saying that in Broadway and many other business parts of New York, where large numbers of telephone wires must of necessity be allowed to occupy the air space, it may be necessary to compel electric light wires to be put underground.

To prevent my remarks in Article 3 from being the cause of mistakes, I wish to state that in using vulcanized rubber cables the joints must be vulcanized by experienced men.

GEORGE FORBES,
34 Great George street.

1890, March 1.

CONSULATE GENERAL OF THE UNITED STATES OF AMERICA FOR GREAT BRITAIN AND IRELAND AT LONDON.

I, John C. New, Consul-General of the United States of America at London, England, do hereby make known and certify to all whom it may concern that John Venn who hath signed the annexed Certificate, is a Notary Public, duly admitted and sworn and practising in the City of London, aforesaid, and that to all acts by him so done full faith and credit are and ought to be given in Judicature and thereout.

IN TESTIMONY WHEREOF, I have hereunto set my hand and affixed my seal of office at London, aforesaid, this first day of March, in the year of our Lord, one thousand eight hundred and ninety.

[SEAL.]

JOHN C. NEW,
Consul-General.

(Postage and Revenue Stamp.)

I, John Venn, of the City of London, Notary Public, duly admitted and sworn practising in said city, do hereby certify and attest:

That the statements hereunto annexed marked "A" and "B" were this day signed in my presence by Dr. John Hopkinson, F. R. S., No. 5 Victoria Street, London, Civil Engineer.

Whereof an Act being required, I, the said Notary have granted these presents under my Notarial Firm and Seal to serve and avail when and where need may require.

Done and passed in London on the first day of March, in the year of our Lord, one thousand eight hundred and ninety.

[SEAL.]

JOHN VENN,
Not. Pub.

ANSWERS OF DR. HOPKINSON.

In this country three companies are using the alternating high tension current for lighting purposes on a considerable scale, the Grosvenor Gallery Company, the Metropolitan Electric Supply Company and the House to House Company. At the present time the major portion of the conductors of the Grosvenor Gallery Company are overhead. The cables are manufactured by the Silvertown Company, and are insulated with india rubber, and carried on separate bearing wires. From the Grosvenor Gallery station this company work at a potential of 2,400 volts. They have been at work since about 1886. So far as I know, only one death has occurred in connection with this system, and that some time ago. In this case a youth appears to have received a shock from the conductor, and to have fallen through a skylight and been killed by the fall; whether he would have been killed or not by his contact with the conductor is unknown. I understand that the Grosvenor Gallery Company have for two years had a pair of Silvertown cables insulated in the same way in a pipe under St. James' Park, and that this cable has not given the slightest trouble of any kind. The Grosvenor Gallery Company, or rather their successors, the London Electric Supply Company, are establishing a station at Deptford for supplying parts of London. From this station it is proposed to supply at a tension of 10,000 volts; but, so far as I am aware, satisfactory working has not yet been attained with so much as 5,000 volts.

The Metropolitan Electric Light Company have at present two stations on the alternating system, both working at 1,000 volts. From Sardinia street at the present time they are supplying about 500 HP, from Rathbone Place about 100 HP. The cables are almost all laid underground. They are Silvertown india-rubber insulated cables laid in iron pipes, several cables in each pipe. With these cables they have had no trouble of any kind, either in the way of

breaking down of insulation or of shocks. The experience of this Company appears to show that it is desirable that the iron pipes should be cast in a vertical position, by so doing chaplets may be dispensed with, which if present tend to leave points within the pipes liable to injure the cable.

The House to House Company have one station at work in London from which they have about 16 miles of cables. These cables are also manufactured by the Silvertown Company and are laid in iron pipes, in the same manner as are the Metropolitan Company's cables. The House to House Company work at a tension of 2,000 volts. They have at present about 6,000 8–c–p lamps connected up and 11,000 wired. I understand that their maximum output is about 55 amperes or 110 kilowatts. The House to House Company have also stations at Eastbourne and Brighton but their London Station is probably the best of the three.

Concerning recent Continental practice I am not prepared to answer from my own knowledge.

I am now in a position to deal with the questions put to me.

1. It has been conclusively proved that alternating high tension currents can be supplied without inconvenience by means of underground conductors if the work is properly done; it has also been proved that this can be done with a potential of 2,400 volts. So far as I know it has not yet been proved that a potential of 5,000 volts can be safely used. This potential, however, is now under experiment.

2. A Silvertown cable in an iron pipe has been in existence under a potential of 2,400 volts, underground in St. James' Park for about two years.

3. I have already indicated the character of the cables used.

4. There is in my opinion no reason whatever why high tension alternating currents should not be used in the street mains.

5. In my opinion there is practically no difference as regards fire risks between the converter system and the direct current system.

6. In my opinion a properly constructed converter with a suitable cut-out is an effectual safeguard to the consumer against danger from shock. As regards fire the precautions must be the same as with the direct current system.

7. In addition to the alternating current system stations there are in this country certain direct current installations. In London there are the St. James's Co., the Chelsea Co. and the Kensington Court Co. In the provinces there is Bradford and there are other places. So far as I am able to judge there seems to be a somewhat larger application of the alternating current than of the direct in London. Taking the whole of the country it is difficult to say ; it is proposed to apply each in many places.

8. The great advantage of the high tension system is that the generating station may be placed at a considerable distance from the work to be done. In cases where the generating machinery can be put close to the work no doubt the direct system would be adopted. But in large towns this is not unfrequently impossible, not alone upon the ground of capital outlay in real estate, but also on the ground that the powerful machinery required would be an annoyance in the neighborhood. Thus, if high tension currents were prohibited it would involve two things for the public, a much greater cost of supply and the annoyance of machinery placed in a place where it is undesirable.

9. The experience of the Grosvenor Gallery Co. shows that high tension alternating currents can be safely distributed by means of overhead conductors ; this has been attained by the use of thoroughly well insulated conductors carried upon independent bearing wires.

10. In my own practice I am guided in the choice of high or low tension entirely by the consideration of where the generating plant is to be placed. If it can be conveniently placed in the immediate neighborhood of the whole of the work to be done, I adopt the direct system of supply at low tension ; if this is not the case, however, I advise the adoption of high tension alternating currents.

(Signed) J. HOPKINSON.

CONSULATE GENERAL OF THE UNITED STATES OF AMERICA FOR GREAT BRITAIN AND IRELAND AT LONDON.

I, John C. New, Consul-General of the United States of America at London, England, do hereby make known and certify to all whom it may concern that John Venn, who hath signed the annexed Certificate, is a Notary Public, duly admitted and sworn, and practicing in the City of London, aforesaid, and that to all acts by him so done full faith and credit are and ought to be given in Judicature and thereout,

IN TESTIMONY WHEREOF, I have hereunto set my hand and affixed my seal of office at London, aforesaid, this [SEAL.] first day of March, in the year of our Lord one thousand eight hundred and ninety.

JOHN C. NEW,
Consul-General.

I, John Venn, of the City of London, Notary Public, duly admitted and sworn, practicing in the said City, do hereby (Postage and Revenue Stamp.) certify and attest :

That the letter hereunto annexed was signed in my presence by William Henry Preece, Esquire, Electrician at the General Post Office, London.

Whereof, an act being required, I the said Notary, have granted these presents under my notarial firm and seal to serve and avail when and where need may require.

Done and passed in London the first day of March, in [SEAL.] the year of our Lord one thousand eight hundred and ninety.

JOHN VENN,
Not. Pub.

ANSWERS OF W. H. PREECE.

1. I have been a persistent and consistent advocate of the high tension system of distributing electrical energy for many years. In a discussion which took place at the Society of Telegraph Engineers and Electricians on April 24, 1884, I said:

" I do not think it is practicable or possible with the figures before us, to light up large areas on any such plan as that which has been conceived (a low tension system). It has been departed from in America, it has been departed from in suggestions here, and the day has come when, if electric currents are to be distributed for economical purposes, for lighting or other purposes, they are not to be distributed by enormous conductors swallowing up capital and ruining everybody, but they are to be smaller conductors in which high tension currents can be utilized and distributed. It may be by secondary batteries, when secondary batteries are made practical. It may be by secondary generators such as we have seen attempted on the Metropolitan Railway, though I do not know that that method has reached its practical stage yet. However, I feel quite satisfied with this, that my figures show that the distribution of electricity for lighting purposes by thick conductors by the parallel system, by such a system as that which has been proposed is, I am afraid, out of the question, because it is financially impracticable."

I have during the six years that have passed since these words were uttered, neither seen nor heard anything to change my views. On the other hand, everything has tended to confirm them. A movement that looks very like an organized conspiracy to decry electric lighting has been operating through the press of this country to impress upon this high-pressure system the stigma that it is highly dangerous to person. Accidents, the result of hurried construction, careless suspension, personal stupidity, and the absence of proper regulations in New York and other cities in the States, have been so

magnified that much fear and diffidence in this system have been established. But in England, where the work done is more substantial, where bare wires suspended on poles along our streets are not allowed; where supervision is organized, and where regulations are extant, there have been, during the past five years, only two fatal accidents; and it is by no means evident that even these were due to the high tension system. (I attach a schedule of the accidents that have occurred in all Europe since 1880.) In London, out of 2,338 fires last year, two only were attributed to the electric wire, while gas is credited with 209.

2. The currents for the alternating current high pressure system in England are safely and successfully distributed both by means of continuously well insulated and properly suspended overhead cables and by means of thoroughly well insulated conductors buried underground in pipes. The voltage used is generally from 1,800 to 2,400 volts.

3. I see no difficulty whatever in maintaining such a system of distributing currents by underground cables, and I form that opinion from actual experience and not from mere theory. Underground cables are safe, durable and efficient. I have had full experience of a high pressure alternating current system in Eastbourne, where such a system working with a voltage of 1,800 volts has been at work since 1886, without a single accident or failure, and is now feeding 2,600 lamps. A similar system of which I have had similar experience has been applied in London at the West Brompton Central Station, 1,800 volts have been distributed for over twelve months through 16 miles of underground wire for lighting purposes throughout the rich and flourishing neighborhood of Kensington without a single failure.

4. I have advised the Metropolitan Electric Supply Company of London to adopt the same system, and they are doing so, and I have also advised several local authorities in England to do the same thing, and they are going to do it.

I do not express my opinion lightly on this subject. There are about 30,000 miles of underground insulated wire of the United

Kingdom under my control, and I have had thirty-seven years' experience of such wires. I venture to think that this experience is unique in its continuity and extent.

5. My view is that there is nothing more practical than 4″ or 6″ cast iron pipes, laid from one to three feet underground in which thoroughly well-insulated and well-protected copper conductors are drawn. There are several insulating materials in the market capable of insulating 2,000 volts, but my experience is chiefly with india-rubber. I see no difficulty whatever in maintaining a pressure of 2,000 volts in underground conduits. It has already been done for eight years in Eastbourne.

N. B.—For 4½ years, 2,000 volts continuous current (Brush) were used.

6. The safety of a high pressure system is entirely a question of precaution, design and care. If the following rule be carried out:

"Alternate current transformers must be supplied with two main fuses, double-pole switch, and an *earthing device* on the secondary circuit, all of which must be securely fixed in a water and fire-proof structure (by preference situated outside the premises) placed under lock and key, and beyond the control of any unauthorized person"—and the work in a house be thoroughly well done and maintained, I can conceive of no danger to person or to building which can arise. The earthing device is a most efficient and satisfactory safety valve. But if maintenance be neglected, if the Cheap Jack and the Jerry builder be admitted, if safety devices are neglected, then the electric system can become as dangerous as gas, and the converter might emulate in insecurity the kitchen boiler or the steam pipe.

7. The system of distribution in houses is essentially a low pressure system, whether the energy be derived from alternate current converters, continuous current batteries or low tension central stations. The high pressure and supposititious danger are confined to the external mains and feeders, which, if kept underground, can be made absolutely safe.

8. There is no more danger of fire from the one system than there

is from the other. Perhaps the low tenslon direct system is the more dangerous of the two, for its fancied security leads to relaxed supervision, while there certainly are conditions when an intense low tension current is more dangerous than a 2.000 volt alternate current. It is an anomaly, though a truism, to say that where there is most danger there is the greater safety; and the reverse is equally true. The reason is that where there is danger there are precautions taken where there is supposed safety, supervision and care cease.

The immunity from accidents on our British railway system, and on our great steam shipping lines is an illustration of what results from careful inspection and proper regulations. A first-class railway compartment on the Midland Railway, or a state saloon on an Atlantic liner, is as safe a position to be placed in as in a drawing room armchair. The system of boiler insurance and supervision in this country has an equally striking and satisfactory result. Boiler explosions are very few and far between.

9. I know no reason why high pressure currents cannot be safely distributed by means of overhead conductors, which are certainly more economical than underground. I append the regulations bearing on the matter which have been issued by the English Board of Trade, which were revised by a Committee of the Institution of Electrical Engineers, and which have been approved of by the Postmaster-General acting on my advice. Such overhead cables have been in use in London for five years with complete success.

10. It is an absurdity to argue that because alternate currents of high pressure will cause death that therefore electric lighting by alternate currents is dangerous. You might as well argue that it is dangerous to eat food with a knife because a man cut his throat in a fit of jealousy: or that it is dangerous to light a fire because a child burnt its finger by picking up a live coal. Danger depends much more upon the personal element than on that of principle. Accidents in all spheres are generally due to carelessness, recklessness or ignorance. More people are killed by blowing out gas than by electric currents, and there are more people killed by the traffic in

the streets of London every week than in the whole of the United States by electricity every year.

Safety (certainly with electricity) is easily purchased by exact design, efficient material, experienced workmanship, proper supervision and careful maintenance, and this can be acquired by high tension alternate currents as readily and as well as by any other form of electrical energy.

(Signed) W. H. PREECE.

These are the regulations referred to in the annexed letter signed by William Henry Preece in my presence this 1st day of March, 1890.

JOHN VENN,
Notary Public.

REGULATIONS FOR THE PROTECTION OF THE PUBLIC SAFETY AND OF THE ELECTRIC LINES AND WORKS OF THE POST-MASTER GENERAL, AND OF OTHER ELECTRIC LINES AND WORKS, PRESCRIBED BY THE BOARD OF TRADE UNDER THE PROVISIONS OF THE ELECTRIC LIGHTING ACT, 1888.

In these regulations the words, terms, and expressions to which by the Electric Lighting Acts, 1882 and 1888, meanings are assigned, shall have the same respective meanings, provided that in these regulations—

"Energy" means electrical energy, and for the purposes of the Electric Lighting Act, 1888, and these regulations, electrical energy shall be deemed to be an agency within the meaning of the word electricity as defined in the Electric Lighting Act, 1882.

"Conductor" means an electric wire or line used for the supply of energy.

"Aerial conductor" means a conductor which is placed above ground and in the open air.

"Low pressure conductor" means a conductor in which the difference of electric potential either between that conductor and earth or between that conductor or any part thereof and any other conductor on the same poles or supports does not exceed 300 volts, if the supply be on the continuous current system, or the equivalent of 150 volts if on the alternating current system. A difference of potential on the alternating current system shall be deemed to be the equivalent of a difference of potential on the continuous current system, when it produces an equal heating effect if applied to the ends of a thin stretched wire or carbon filament.

"High pressure conductor" means a conductor in which the difference of electric potential as above described is greater than that of a low pressure conductor.

REGULATIONS.

1. An aerial conductor in any street shall not in any part thereof be at a less height from the ground than 20 feet, or where it crosses a street, 30 feet, or within six feet of any building or erection other than a support for the conductor, except where brought into a building for the purpose of supply.

2. Every aerial conductor shall be attached to supports at intervals not exceeding 200 feet where the direction of the conductor is straight, or 150 feet where this direction is curved, or where the conductor makes a horizontal angle at the point of support.

3. Every support of aerial conductors shall be of a durable material, and properly stayed against forces due to wind pressure, change of direction of the conductors, or unequal lengths of span, and the conductors and suspending wires (if any) must be securely attached to insulators fixed to the supports. The factor of safety for the suspended wires shall be at least 6, and for all other parts of the structure at least 12, taking the maximum possible wind pressure at 50 pounds per square foot. No addition need be made for a possible accumulation of snow.

4. Every support, if of metal, shall be efficiently connected to earth, and if of wood or other non-conducting material, shall be protected from lightning by a lightning conductor fastened to the sup-

port along its entire length, and projecting above the support to a height of at least six inches, such lightning conductor being efficiently connected to earth.

A support shall be efficiently connected to earth when it is connected to metallic mains for water supply outside of buildings, or, where these are not available, to a mass of metal having a total surface of at least four square feet, buried to a depth of at least three feet in moist earth, provided that in either case the connecting conductor must possess a mechanical strength, and offer a passage to electrical discharges, equal to that of a strand of seven No. 16 galvanized iron wires.

5. Every aerial conductor shall be protected by efficient lightning protectors of pattern approved by the Board of Trade.

6. Where any conductor crosses a street, the angle between such conductor and the direction of the street at the place of such crossing shall not be less than 60 degrees, and the spans shall be as short as possible.

7. Where any aerial conductor is erected so as to cross any other aerial conductor or any suspended wire used for purposes other than the supply of energy, precautions shall be taken by the owners of such crossing conductor against the possibility of that conductor coming into contact with the other conductor or wire, or of such other conductor or wire coming into contact with such crossing conductor by breakage or otherwise.

8. The maximum working current in any aerial conductor shall not be sufficient to raise the temperature of the conductor in any part to such an extent as to materially alter the physical condition of specific resistance of the insulating covering, if any, or in any case to raise such temperature to a greater extent than 30° of Fahrenheit's thermometer, and efficient automatic means shall be provided which will render it impossible for this maximum working current to be by any accident exceeded to the extent of 25 per centum, even for short intervals of time; and special care shall be taken that the cross sectional area and conductivity at joints is sufficient to avoid local heating, and that the joints are protected against corrosion.

9. Every high pressure aerial conductor must be continuously insulated with a durable and efficient material to be approved by the

Board of Trade, to a thicknes of not less than one-tenth part of an inch, and in cases where the extreme difference of potential in the circuit exceeds 2,000 volts, the thickness of insulation must not be less in inches or parts of an inch than the number obtained by dividing the number expressing the volts by 20,000. This insulation must be further efficiently protected on the outside against injury or removal by abrasion. If this protection be wholly or partly metallic it must be efficiently connected to earth, so, however, as not to cause undue disturbance to other electric lines or works by electrostatic induction or otherwise.

10. The material used for insulating any high pressure aerial conductor must be such as will not be liable to injurious change of physical structure or condition when exposed to any temperature between the limits of 10° F. and 150° F., or to contact with the ordinary atmosphere of town or manufacturing districts.

11. The insulation resistance of any circuit using high pressure aerial conductors, including all devices for produciug, consuming or measuring energy, connected to such circuit, shall be such that should any part of the circuit be put to earth, the leakage current shall not exceed $\frac{1}{25}$th of an ampere in the case of continuous currents, or $\frac{1}{50}$th of an amper in the case of alternating currents. Every such circuit containing high pressure conductors shall be fitted with an indicating device which shall continuously indicate if the insulation resistance of either conductor fall below the conditions required by this regulation.

12. Every aerial high pressure conductor shall be efficiently suspended by means of non-metallic ligaments to suspending wires, so that the weight of the conductor does not produce in it any sensible stress in the direction of its length, and the insulated conductors and suspending wires, where attached to supports, shall be in contact only with material of highly insulating quality, and shall be so attached and guarded that in case they break away it shall not be possible for them to fall away clear of the support.

13. In the case of aerial conductors carrying alternating currents the two conductors constituting the line and return for any circuit shall be run parallel with each other, and at a distance apart not exceeding eighteen inches.

14. The owner of every aerial conductor shall be responsible for the efficieney of every support to which such conductor is attached, and every support shall be efficiently marked with such mark indicatins the ownership of the conductor as the Board of Trade shall approve.

15. Every aerial conductor, including its supports and all the structural parts and electrical appliances and devices belonging to or connected with such conductor shall be duly and efficiently supervised and maintained by or on behalf of the owners as regards both electrical and mechanical conditions.

16. An aerial conductor shall not be permitted to remain erected after it has ceased to be used for the supply of energy, unless the owners of such conductors intend within a reasonable time again to take it into use.

17. Every aerial conductor shall be placed and used with due regard to electric lines and works from time to time used or intended to be used for the purpose of telegraphic communication or the currents in such electric lines and works, and every reasonable means shall be employed in the placing and the use of aerial conductor to prevent injurious affection, whether by induction or otherwise, to any such electric lines or works or the currents therein.

18. (*a*) A notice describing every aerial conductor erected or used for the supply of energy shall forthwith, upon receipt of these regulations, be served upon the Postmaster-General, together with a plan showing the mode and position in which such conductor is erected.

(*b*) The Postmaster-General, upon consideration of such notice and plan, may require such alteration in the position or mode of erection, or mode of use of such conductor, or compliance with such other conditions as he may think fit, having regard to the protection of the electric lines or works of the Postmaster-General, and any failure on the part of the body or person owning or using, or entitled to use, the said conductor to comply with such requirements as shall be deemed to be a non-compliance with these regulations.

(*c*) Any notice required to be served upon the Postmater-General under these regulations may be served by being addressed to him

and left at, or transmitted through the post to the General Post-office, London, and any notice required to be served on the body or person owning or using, or entitled to use, any aerial conductor may be served by being addressed to such body or person and left at, or transmitted through the post to, their or his office or last known place of address.

CONSULATE GENERAL OF THE UNITED STATES OF AMERICA FOR GREAT BRITAIN AND IRELAND AT LONDON.

I, JOHN C. NEW, Consul-General of the United States of America at London, England, do hereby make known and certify to all whom it may concern that Douglas John Newton, who hath signed the annexed certificate, is a Notary Public, duly admitted and sworn and practicing in the City of London, aforesaid, and that to all acts by him so done full faith and credit are and ought to be given in judicature and thereout.

In testimony whereof I have hereunto set my hand and affixed my seal of office at London, aforesaid, this
[SEAL.] 27th day of February, in the year of our Lord, one thousand eight hundred and ninety.

JOHN C. NEW,
Consul-General.

I, Douglas John Newton, Notary Public by Royal authority, duly admitted and sworn, practicing in London, do hereby certify unto all whom it shall or may concern that the signature "E. Fesquet" set at foot of the answer hereunto annexed, paged from 3 to 5 inclusive, to the questions also hereunto and paged 1 and 2, is the real and genuine signature of Mr. Emile Fesquet, the engineer of the National Company for the distribution of electricity by Secondary Generators, Limited, of 18 Warwick street, Regent street, London, which said signature was this day subscribed in my presence.

Whereof, an act being required, I, the said Notary, have granted these presents under my notarial firm and seal of office to serve and and avail as occasion shall or may require.

Done and passed in London this twenty-seventh day of
[SEAL.] February, one thousand eight hvndred and ninety.

(Postage and Revenue Stamp.)

In testimonium veritatis.

DOUGLAS J. NEWTON,
Not. Pub.

ANSWERS OF E. FESQUET.

1. Direct and alternating currents of high tension for lighting and power can safely and successfully be distributed by means of underground cables, provided ordinary precautions known to all electricians are taken. In my own experience I have used 3,000 volts. An installation I put up at Tours in France has a primary alternating current of 2,500 volts, and has been running satisfactorily during four years without accident of any kind. The conductors in this case are underground-

2. My opinion is based on practical experience extending over ten years, during which I have been entirely employed in alternating current work. Since 1885 a central station in London has been distributing light by means of alternating current of 2,400 volts and transformers, by means of conductors which are partly overhead and partly underground. the number of lamps supplied being about 20,000. Other companies have since been working in London and Provincial towns, with alternating currents of 2,000 to 2,500 volts. One alternating current plant has a tension of only 1,000 volts.

I put up a station in Germany in 1885 when the alternating current used was 2,500 volts. The conductors were overhead—the number of lamps being about 2,500. This station has worked up to the present time with perfect success and without accident.

I also put up a station in Italy in 1885 when the alternating current used was 2,500 volts—the conductors being overhead—the number of lamps about 500. The working has been regular, successful and without accident.

3. The conducting cables used in England. France, Germany and Italy, by me, have been India rubber covered cables, not concentric—

the latter being laid parallel to prevent induction. When cables are laid underground, I use a cast-iron pipe or wooden trough filled with bitumen, the cable being supported by bridges.

4. The converter or transformer system involving the use of high tension alternating currents, can be used with absolute safety to the consumer and the public at large, No accident can happen if well known precautions are taken and the neglect of them implies great ignorance.

5. The fire danger in a properly arranged transformer or converter system, may be made much less than in the low tension direct current system, the large quantity necessarily carried by the latter being always a source of danger besides, its main system must always be directly connected with the house service, and no amount of protection fuses can alter the fact.

In a direct current system distributing mains and house circuits being connected, it is difficult to detect the exact spot where a leak may have occurred, but in the transformer system, a leak in the conductors inside the houses of consumers, can never be connected with the distributing main, and the position of a leak in this latter is easily detected.

6. Yes. Under proper conditions.

7. The present development in Europe, including London, is greatly in favor of the alternating system.

8. The high tension systems, both with direct and alternating currents, are essential to an economical distribution of light and power—the possibility of using water power at a distance is itself an element in the question which is an obvious advantage; even if steam power is used, it can be done more economically outside a town; then the possibility of concentrating at one point the motive power required for supplying a large district with light is an immense advantage from an economical point of view: it is probably the possibility of establishing central stations, to supply large areas from

which may be considered to start the general application of electricity. If all lighting and power work were done exclusively by means of low tension direct current the advantages within the reach of all would be withheld until a wiser generation should arise to take advantage of the facilities offered by the high tension system. By every direct system the consumer can use only one kind of lamp; by means of converters the consumer can select any type of lamp.

9. I have put up several overhead conductors for alternating current at high tension. The poles I have used have been generally iron, the insulators of porcelain, the india-rubber covered conducting cable has been sometimes supported by a steel wire. Storms that have wrecked telegraph and telephone wires have left my conductors uninjured, and I have never had any accident from the current during my experience of ten years.

10. I consider that substantial, safe and reliable work can be done at prices which will enable a good profit.

(Signed) E. FESQUET,
Engineer of the National Company for the Distribution of Electricity by Secondary Generators, Limited,
18 Warwick Street, Regent Street, London.